GFZ Analysis Center 2014 Annual Report

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Abstract This report briefly provides general information and the component description of the IVS Analysis Center at GFZ. Recent results are mentioned, and the planned future activities are outlined.

1 General Information

Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences is the national research center for Earth sciences in Germany. Main tasks of GFZ according to its website[1] are:

> *System Earth — Research Focus of the GFZ German Research Center for Geosciences*
>
> *The Earth is a dynamic planet. Under the influence of external and internal forces, it is continuously changing. The solid Earth, the atmosphere, the hydrosphere and the things living within them are always interacting. In short, the Earth is a complex system, with forces and interactions between many different partners. To understand the world in which we live, from our regional environment to the entire planet, it is necessary to understand how the System Earth works in all details. In the analysis, we have to include the activities of mankind and their influence on the natural processes in this complex, nonlinear system, which in turn affects the environment we live in.*
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> *The overarching research aim of the GFZ is one of developing strategies and demonstrating practical options, e.g. to preserve natural resources and to exploit them in an environmentally friendly way, to guard against natural catastrophes, to assess changes in the climate and the environment and man's impact on these, and to research and utilise our world below ground, all based on a comprehensive understanding of systems and processes.*

At this research facility within Department 1 'Geodesy and Remote Sensing' and Section 1.1 'GPS/GALILEO Earth Observation' a VLBI group that is an associate Analysis Center (AC) of IVS has been estabilshed since the end of 2012.

2 Component Description

GFZ is an associate AC of IVS. We are installing and automatizing our VLBI analysis process in preparation for becoming an operational AC. We analyze all incoming geodetic and astrometric types of sessions and provide interim results in the SINEX format within 24 hours after the provision of database files of version 4 or higher at IVS Data Centers. In 2013 and 2014 we re-processed all available IVS databases and submitted these for inclusion in the IVS contribution to the ITRF2014 (formerly ITRF2013). We are also performing as an IVS Combination Center for tropospheric products [6][2].

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[1] http://www.gfz-potsdam.de

[2] http://kg6-dmz.gfz-potsdam.de/ivs/php/tropospheric_combination.php

3 Staff

The members of the VLBI group and their functions are listed in Table 1, and a picture of us is displayed as Figure 1. In 2014, Virginia Raposo-Pulido visited the Observatoire de Paris, Paris, France, for several months to cooperate with Nicole Capitaine and Sébastien Lambert on the determination of systematic effects of the CRF. Julian Mora-Diaz visited the Max Planck Institute for Radio Astronomy, Bonn, Germany, for a few weeks to determine radio source structure maps together with Alessandra Bertarini.

Since last year (Annual Report 2013) two more scientists and one PhD student joined our VLBI group (in alphabetical order):

- James M. Anderson, PhD, is a radio astronomer, who studied at NRAO, USA, and who has been in the past working e.g. at JIVE, The Netherlands, and at MPI Bonn, Germany,
- Kyriakos Balidakis, MSc, is a geodesist from Aristotle University in Thessaloniki, Greece, who will be working on atmospheric modelling for space geodetic techniques for his PhD, and
- Susanne Glaser, Dr.-Ing., a geodesist from Technische Universität Dresden, Germany, focussed in the past on ITRF computation and combination strategies.

Table 1 Members of the VLBI group at GFZ without MSc students.

Name	Main activity
Harald Schuh	Head of Department 1 at GFZ
Robert Heinkelmann	Head of VLBI group
Tobias Nilsson	Head of software development
James Anderson	Satellite observations, D-VLBI
Kyriakos Balidakis	Atmospheric effects
Susanne Glaser	Simulations w.r.t. GGOS
Maria Karbon	Kalman filtering, EOP
Li Liu	Satellite observations
Cuixian Lu	Atmospheric effects
Julian Mora-Diaz	CRF, source structure
Virginia Raposo-Pulido	CRF, systematic effects
Benedikt Soja	Kalman filtering, atmosphere
Minghui Xu	CRF

Fig. 1 The GFZ VLBI group and guests in September 2014 for the farewell of our guest Santiago Belda-Palazón (University of Alicante, Spain) and the welcome of Dr. Alexei Lapshin (Moscow State University of Geodesy and Cartography) at Wirtshaus Moorlake, Berlin-Wannsee. Missing colleagues: Cuixian Lu and Virginia Raposo-Pulido.

4 Current Status and Activities

- **IVS Operational Analysis Center at GFZ**
  At GFZ we are preparing to become an operational AC of the IVS. Therefore, starting in mid 2014 we entered into the test phase. In accordance with the test phase, we are now analyzing all new rapid turnaround sessions, and we submit our SINEX files within one day after the version 4 (or higher) databases become available. Until the end of the test phase the GFZ contribution is being used for the official products but with a very small weight compared to operational ACs. During 2014, routines have been established and have been continuously improved in order to run the complete analysis chain as smoothly as possible, and several steps (such as downloading files necessary for analysis) have been completely automated. Doing so, wherever possible we already consider the future VGOS situation, where many routines applied today will have to be revised or have to deal with significantly more data and different data formats. In 2015 we will continue optimizing these routines, as well as improving our analysis setup including the valuable feedback we get from the IVS Combination Center at BKG. Hopefully we will be accepted as an operational AC in the near future.
- **Contribution to ITRF2014**
  We made a complete reanalysis of all VLBI data available from IVS servers from 1979 until now. A part of the results of the reanalysis has been submitted for inclusion in the IVS contribution to the

ITRF2014. Statistics of the solution and first results are presented in [3].

- **VLBI Data Analysis using Kalman Filtering**
  At GFZ we are developing our own version of the Vienna VLBI Software (VieVS, [1]), named VieVS@GFZ. Currently, a main part of this work is the implementation of a Kalman filter as an alternative to the single session least squares solver. The developments are funded by the research project *VLBI analysis in real-time (VLBI-ART)* (Austrian Science Fund FWF, project no. 24187). In 2014 a first version of the Kalman filter was completed that — as we believe — provides results of the same quality or better than those obtained with the least squares [4].
- **Space Applications**
  The main research topic of the VLBI group at GFZ is the analysis of VLBI observations to spacecraft. Here, in the project *Ties between kinematic and dynamic reference frames (D-VLBI)* (Deutsche Forschungsgemeinschaft DFG, project no. SCHU 1103/4-1) we have been extending our VLBI analysis software VieVS@GFZ for group delay and differential VLBI observations to spacecraft, e.g. GNSS satellites [5], and to extragalactic radio sources. In 2015, we plan to perform differential VLBI observations towards various satellites and interplanetary spacecraft, such as RadioAstron, Gaia, and GNSS.
- **Simulation of the Global Geodetic Observing System**
  Within the project *GGOS-SIM: Simulation of the Global Geodetic Observing System* [3] (DFG, project no. SCHU 1103/8-1), Dr.-Ing. Susanne Glaser, our guest scientist from TU Berlin, will perform simulations of all four space geodetic techniques involved in ITRF computation: DORIS, GNSS, SLR, and VLBI together with colleagues from GFZ at Oberpfaffenhofen, Germany. The main goal of the project is to assess to what extent the ITRF can be improved by involving additional terrestrial co-location stations or by having several techniques co-located in space, e.g. onboard GRASP (Geodetic Reference Antenna in Space), a planned NASA mission.
- **Twin Telescope Simulations**
  We have tested advanced analysis methods by performing simulations for the future VGOS network in cases where stations operate more than one antenna, e.g. so-called twin telescopes. More specifically, we investigated to what extent it is possible to combine the tropospheric parameters of these antennas in order to improve the data analysis. We found that this approach improves the estimated station coordinates as long as the separation between the antennas is smaller than about 1 km [8, 9].
- **Homogenization of Pressure Data**
  In 2014, we started a process of calibration and homogenization of the long time series of pressure measurements (and other meteorological parameters) recorded at the IVS stations. This will be achieved involving pressure from numerical weather prediction models as well as measurements from surrounding WMO meteorological stations. At the end of the process we will have identified and removed biases, jumps, and other inhomogeneities in the long pressure time series, and at the same time we will have calibrated the mean value which will improve the accuracy. It is very important to have high quality pressure measurements for the VLBI data analysis for obtaining accurate zenith wet delay estimates because these parameters correlate with other parameters such as station coordinates [2].
- **Celestial Reference Frame**
  Several studies related to improving the celestial reference frame (CRF) were performed. For example, we have studied the apparent proper motion of the ICRF2 special handling and other radio sources [7] and obtained source structure maps. Other subjects in this context were considerations about the datum definition [10, 11] and about the CRF systematics, such as the aberration caused by the acceleration of the ICRS origin [13]. Part of the work done here was funded by the project *ECORAS - extension of the coordinate parameterization of radio sources observed by VLBI* (DFG, project no. HE 5937/2-1).
- **Solar Corona Modeling**
  In 2014 we continued studies related to measuring the electron density of the solar corona by VLBI observations angularly close to the Sun. The innovative approach and results are highlighted in [12].

[3] http://www.earth.tu-berlin.de/menue/forschung/projekte/ggos-sim

5 Future Plans

The following activities are planned for 2015:

- Continuing our current investigations.
- Furthering the development of the software VieVS@GFZ. In particular we want to implement the bandwidth synthesis ambiguities and ionospheric delay determination as part of our VieVS@GFZ version. Development is also foreseen for preparing the software for VGOS.

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